Bulletin 5E-H

Schutte & Koerting

Steam Jet Ejectors

Introduction

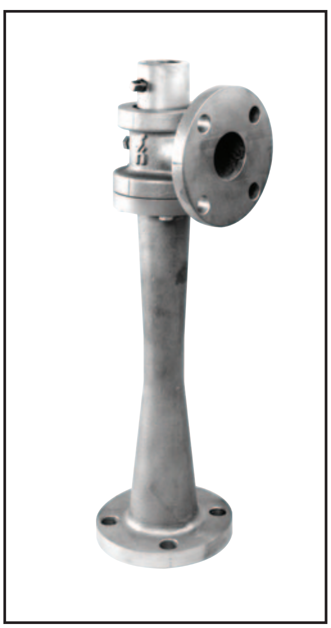
Schutte & Koerting has a century of experience in designing and building efficient jet vacuum ejectors. This vast experience allows S & K to handle virtually any jet ejector application—no matter how complex.

Steam Jet Ejectors are based on the ejector-venturi principle. In operation, steam issuing through an expanding nozzle has its pressure energy converted to velocity energy. A vacuum is created, air or gas is entrained and the mixture of gas and steam enters the venturi diffuser where its velocity energy is converted into pressure sufficient to discharge against a predetermined back pressure.

Jet vacuum ejectors are readily available in ductile iron, steel, stainless steel and, on special order, in many more materials such as Monel, Alloy 20, Hastelloy, Silicon Carbide, Titanium, Bronze and others. They can also be made from a variety of nonmetals such as Phenolic FRP (previously supplied as Haveg), Graphite and Teflon.

Steam jet ejectors are used in the process, food, steel and allied industries in connection with such operations as filtration, distillation, absorption, mixing, vacuum packaging, freeze drying, dehydrating and degassing. They will handle both condensable and non-condensable gases and vapors as well as mixtures of the two. Small amounts of solids or liquids will not cause operating problems. Accidental entrainment of liquid slugs can cause momentary interruption in pumping, but no damage to equipment.

All S & K ejectors are computer designed and type-tested to insure reliability.



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Advantages

The principal advantages of steam jet ejectors over other types of vacuum producing units are...

Low Cost. Pumps of the ejector type are small in relation to the work they do and their cost is low in comparison with other types of equipment.

No **Moving Parts.** These units have no moving parts to adjust or repair.

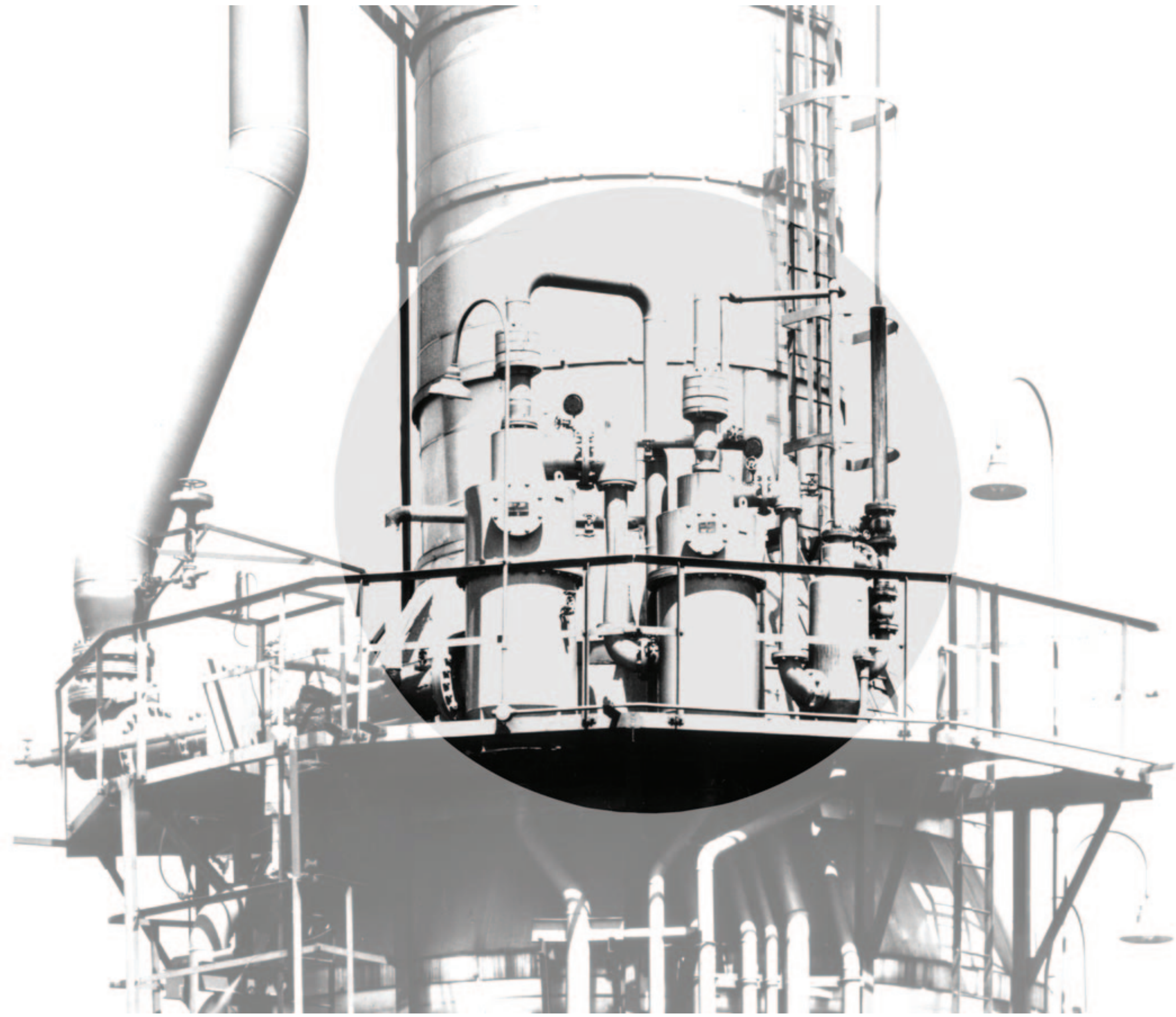
Simple, Compact Construction. Nothing could be simpler than a jet vacuum ejector. It consists of an expanding nozzle, a body, and a venturi (or diffuser).

Reliability. Because of their inherent simplicity, these pumps are reliable. Maintenance requirements are simple and are easily accomplished.

Corrosion/Erosion Resistance. Units can be made in practically any workable material to provide utmost resistance to corrosion and erosion. Standard models are supplied in a choice of materials as indicated in this bulletin.

Easy Installation. Relatively light in weight, jet ejectors are easy to install, require no foundations. Even multi-stage units are readily adaptable to existing conditions.

High Vacuum Performance. Steam jet ejectors can handle air or other gases at suction pressures as low as three microns Hg. abs.



Performance Characteristics

The graph, Fig. 3, shows the relative suction pressure capabilities of S & K Steam Jet Ejectors from single-stage through six-stage types. It can be seen that in some cases units overlap. When this occurs, a detailed comparison of initial costs and steam consumption should be made before making a decision as to the exact type required to meet specific requirements. S & K engineers should be consulted for their recommendations based on experience in many applications. Single-Stage Ejectors are made in several models to meet various suction pressure requirements. Fig. 4 shows the range of suction pressure offered by each model.

A feature of the standard S & K line is that users can select a size ideally suited for individual requirements. In addition, a new and carefully tested design provides far greater capacities than ever before available. The smallest size unit now covers a range that previously required two ejectors of earlier design.

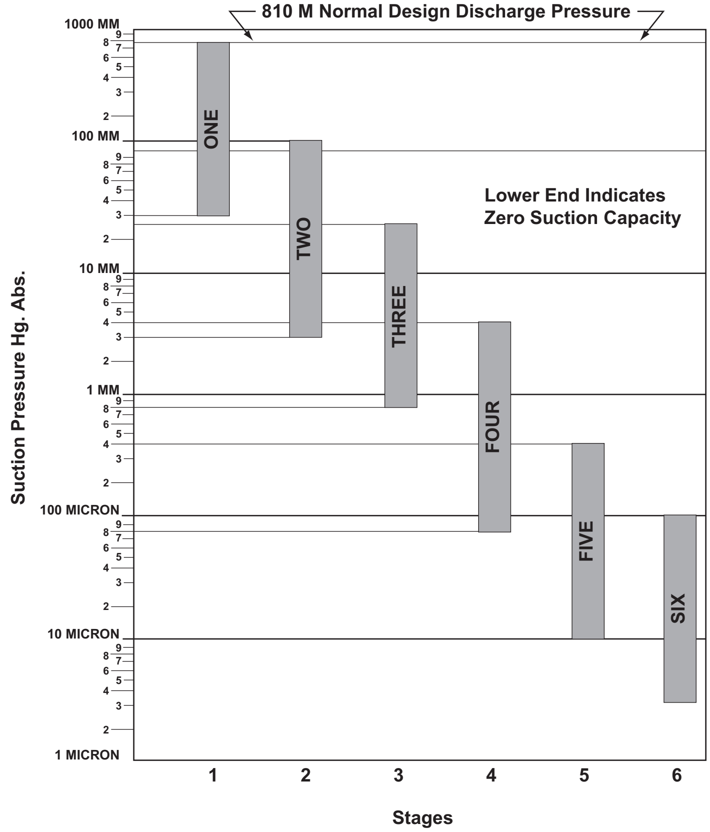


Fig. 3. Suction Pressure Ranges of Single and Multi-Stage Steam Jet Ejectors.

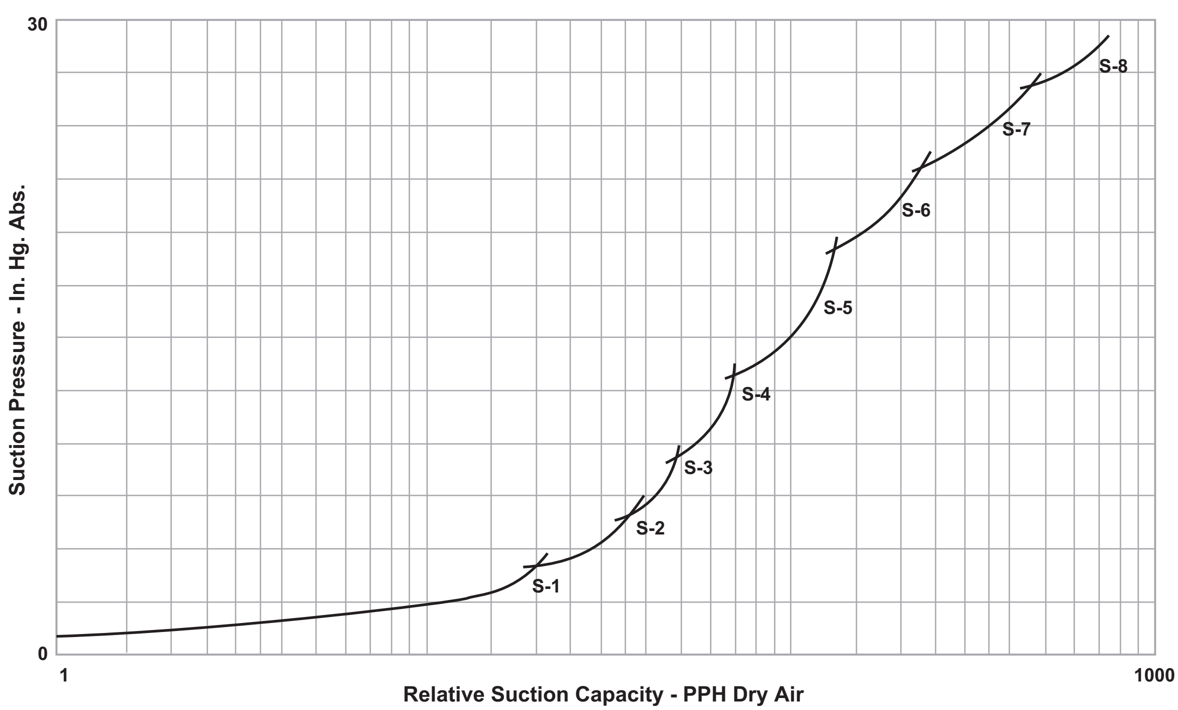


Fig. 4. Suction Pressure Ranges of Single-Stage Ejectors.

SINGLE-STAGE EJECTORS

FIG. 556 STANDARD CONSTRUCTION

Application

S & K Single Stage Ejectors are designed to cover a suction pressure range from 1" to 30 " Hg Absolute utilizing eight specific internals as shown in Fig. 4, page 3 and are used in applications of the types noted on page 1.

Each of the "S" types indicated will produce the most economical performance in its specific suction pressure range.

Construction

The standard Fig. 556 Single Stage Ejector comprises a converging-diverging steam nozzle, a body or suction chamber, and a venturi tail (diffuser).

Sizes 1" through 3" are cast in ductile iron or stainless steel with Type 316 stainless steel steam nozzle. Sizes 4", 5" and 6" are constructed of ductile iron or stainless steel body but tails are fabricated from steel. Details of construction and dimensions are shown in Figures 6, and 7. The standard primary stage of a two-stage ejector system (page 11), designated as Fig. 541, is constructed in the same manner and externally follows the dimension in Table 1.

Sizes above 6" are made to special order and are generally 100% fabricated.

Ductile iron has strength characteristics similar to steel while retaining many desirable features of cast iron. It is often used as a substitute for steel. Units, however, can be supplied in steel, stainless steel and other alloy utilizing barstock diffusers (see page 1).

S & K maintains sufficient parts inventory to assure component availability in all standard sizes in ductile iron and stainless steel for fast turnaround.

On special orders, ejectors can be supplied in Steel, Monel, Alloy 20, Hastelloy, Titanium, Teflon, Phenolic FRP (previously supplied as Haveg), Graphite (pages 5 and 6) and many other materials.

Fig. 5. Fig. 556 Steam Jet Ejector.

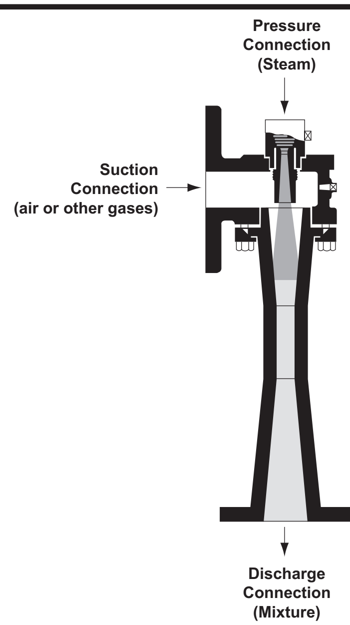


Fig. 6. Fig. 556 Steam jet Ejector. This design is standard for models with 1", 1 1/2", 2", 2 1/2", 3" and 4" suction connections.

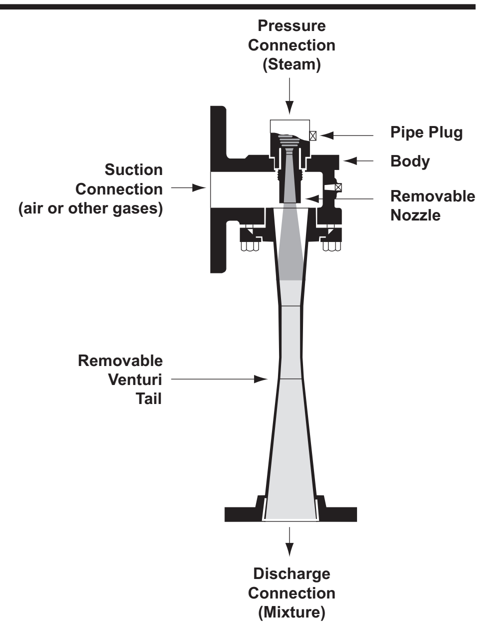
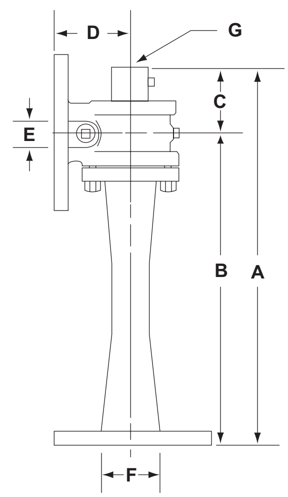


Fig. 7. Fig. 556 design for models with 5" and 6" suction connections.

Table 1. Sizes and Dimensions of Fig. 556 Ejectors (Standard Construction)

Size in Inches	Unit Dimensions				Connections			Net Weight (Lbs.)
	A	B	C	D	E	F	G	
1	11 19/64	8 7/8	2 27/64	2 7/8	1	1	3/4	14
1 1/2	16 7/16	13 1/4	3 3/16	3 3/8	1 1/2	1 1/2	1	18
2	21 9/16	17 11/16	3 7/8	3 5/8	2	2	1 1/4	36
2 1/2	26 41/64	22 1/16	4 37/64	3 7/8	2 1/2	2 1/2	1 1/2	65
3	31 43/64	26 7/16	5 15/64	4 5/8	3	3	2	83
4	42 27/64	35 5/16	7 7/64	5 7/8	4	4	2 1/2	105
5	53 55/64	45 7/8	7 63/64	7 1/2	6	5	3	300
6	64 21/64	54 1/2	9 53/64	7 1/2	6	6	3	450

Note: Suction and discharge flanges are 150 lb. ANSI.



SINGLE-STAGE EJECTORS

FIG. 556 TEFZEL-LINED STEAM JET EJECTORS FOR CORROSIVE APPLICATIONS

The Tefzel® -Lined Steam Jet Ejector is designed for use in corrosive applications. The unit is available in standard sizes up to 6” and custom fabricated for larger sizes. This ejector is designed as an alternative to Phenolic FRP (previously supplied as Haveg) or graphite steam jets, which are typically fragile and prone to breakage during installation and operation.

This Steam Jet Ejector is fabricated with a SST steel body and diffuser lined with 100 mils of Tefzel®. Tefzel®, created by Dupont, is a fluoropolymer resin that offers high chemical, abrasion and temperature resistance. Tefzel® is inert to strong mineral acids, inorganic bases, halogens and metal salt solutions. Even carboxylic acids, anhydrides, aromatic and aliphatic hydrocarbons, alcohols, aldehydes, ketones, ethers, esters, chlorocarbons and classic polymer solvents have little effect on Tefzel®.

The Tefzel® Steam Jet Ejector, as a single-stage ejector, is capable of suction pressure ranges from 1” to 29” hg abs. Multiple units can be staged together in condensing or non-condensing configurations to 5 stages and produce vacuum levels to 500 microns. The use of Tefzel® -Lined ejectors in conjunction with carbon black condensers can provide a very economical solution for corrosion resistant vacuum systems.

The design of the ejector utilizes our standard ejector body and diffuser, which is over-machined and lined with 100 mils of Tefzel®. This design provides for an ejector with exceptional corrosion resistance as well as mechanical strength. The motive connection has been modified from our standard design to accept a clamp-in steam nozzle that can be supplied in graphite or any corrosion resistant metal. The new ejector is available with 150# suction and discharge flanges and dimensions that match our standard ejector.

Schutte & Koerting can also supply complete corrosion resistant package systems utilizing our new Tefzel® - Lined Steam Jet Ejectors in conjuction with corrosion resistant piping and condensers. Our experienced staff of design engineers will create a skid-mounted system with single point utility connections to meet your specifications. Once the system is assembled in our facility, it is moved to our Test Floor, where it is fully performance-tested to design conditions. Our state-of-the-art data collection system compiles the performance data during the entire test. This information is used to provide a certified performance curve and test data, which can be used in the field to verify process performance.

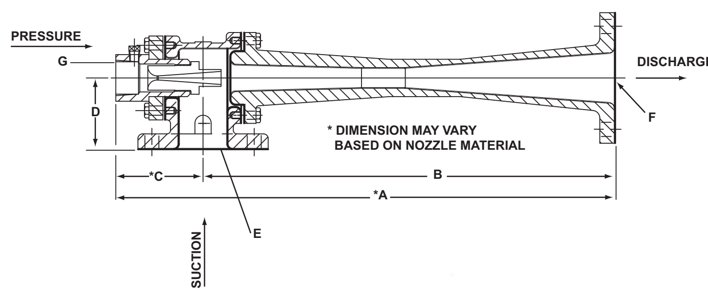


Table 2. Sizes and Dimensions of Fig. 556 Tefzel-Lined Steam Jet Ejectors

Size (In Inches)	Unit Dimensions				Connections			Net Weight (Lbs.)
	A	B	C	D	E	F	G	
1	11 19/64	8 7/8	2 27/64	2 7/8	1	1	3/4	14
1 1/2	16 7/16	13 1/4	3 3/16	3 3/8	1 1/2	1 1/2	1	18
2	21 9/16	17 11/16	3 7/8	3 5/8	2	2	1 1/4	36
2 1/2	26 41/64	22 1/16	4 37/64	3 7/8	2 1/2	2 1/2	1 1/2	65
3	31 43/64	26 7/16	5 15/64	4 5/8	3	3	2	104
4	42 27/64	35 5/16	7 7/64	5 7/8	4	4	2 1/2	203
5	53 55/64	45 7/8	7 63/64	7 1/2	6	5	3	300
6	64 21/64	54 1/2	9 53/64	7 1/2	6	6	3	450

SINGLE-STAGE EJECTORS

FIG. 555H PHENOLIC FRP (PREVIOUSLY SUPPLIED AS HAVEG) CONSTRUCTION

Application

Designed for handling many solvents, as well as acids and corrosive vapors, Fig. 555H Steam Jet Ejectors are made from Phenolic FRP (previously supplied as Haveg) of various types. Phenolic FRP resists rapid temperature change and can be used continuously with temperatures as high as 265° F. It is durable and has excellent resistance to corrosion.

Construction

The standard unit is constructed of Phenolic FRP with a graphite nozzle. Phenolic FRP is a furfuryl alcohol-formaldehyde resin with a non-asbestos silicate filler and is used for body and diffuser. A high grade of impervious Graphite is used for the steam nozzle. Special applications may require a different grade of Phenolic FRP material.

The Fig. 555H Ejector has a one-piece molded Phenolic FRP body and diffuser - eliminating a joint between these parts, a steel steam chest and a steam nozzle of Graphite. The bolts holding the steam chest extend the full length of the exhauster and fasten to the exhaust pipe. This holds the body and diffuser in compression and eliminates any tendency of the diffuser to break away from the body.

Dimensions and sizes of 1” to 4” Fig. 555H Phenolic FRP Ejectors are shown below. Phenolic FRP is a plastic material which has been subjected to thermal processing and pressure. Jet ejectors made from this material in the grades available are tough and durable and are resistant to many acids, bases, and salts.

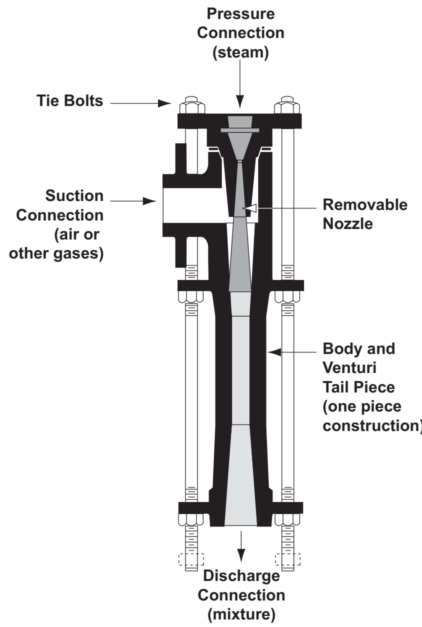


Fig. 9. Fig. 555H Phenolic FRP Ejector.

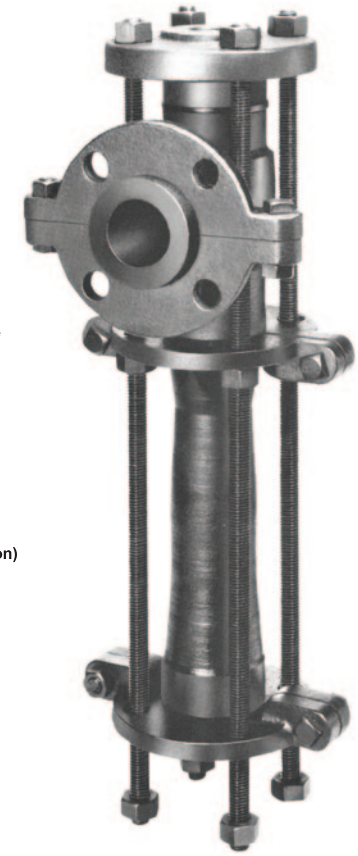
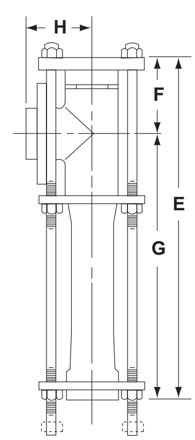


Fig. 10. Fig. 555H Steam Jet Ejector made of Phenolic FRP. Nozzles are interchangeable with those used in the Type 562 Ejector described on page 6.

Table 3. Sizes and Dimensions of Fig. 555H Ejector (Phenolic FRP Construction)

Size No. (Inches)	Connections			Dimensions				Approx. Shipping Wgt. (Lbs.)
	Suction	Discharge	Steam Inlet	E	F	G	H	
1	1 1/2	1 1/2	1/2	17 1/4	4	13 1/4	4	18
1 1/2	1 1/2	2	1/2	17 1/4	2 1/2	13 1/4	4	18
2	2	2 1/2	3/4	22 5/16	3	17 11/16	4 1/2	27
2 1/2	2 1/2	3	3/4	27 5/16	3 1/2	22 1/16	5	38
3	3	3	1	32	4 1/4	26 7/16	5 1/2	51
4	4	3	1 1/4	43 7/16	5 1/4	35 5/16	6 1/2	76
5	5	4	1 1/4	ON APPLICATION				
6	6	5	3					
8	8	6	3					



SINGLE-STAGE EJECTORS

FIG. 562/555G GRAPHITE CONSTRUCTION

Application

This type Steam Jet Ejector is designed to resist the corrosive effects of vapors from a large number of acid and salt solutions.

Construction

Specially constructed to make it non-porous and immune to the effects of the vapors mentioned above, this Single-Stage Ejector has a bronze steam chest, an impervious Graphite body, nozzle, and tail bushing. External fiberglass armoring (Fig. 555G), which will add strength and assist in withstanding the effects of corrosion, is provided in 4", 5 ", 6", and 8" sizes. (See Fig. 13.)

A number of features make the design of this ejector noteworthy. In addition, the Graphite is specially impregnated to avoid leakage.

The steam chest is equipped with a stainless steel steam strainer basket which is retained in place by a strainer plug. The strainer plug is fitted with a pipe plug for easy inspection of nozzle and strainer without removing steam lines or strainer assembly. This plug may also be used to connect a steam pressure gauge.

The diffuser and steam nozzle are accurately machined for maximum steam economy. Dimensions and sizes from 1 1/2" to 6" are shown below.

Fig. 12. Fig. 562 Steam Jet Ejector, constructed of impervious Graphite. Ejectors with 4" and above suction and pressure connections have fiberglass armoring. Nozzles are interchangeable with those used in the Fig. 555H Pump described on page 5.

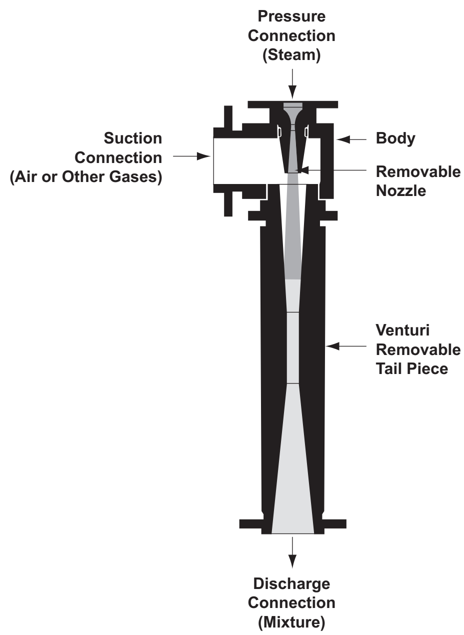


Fig. 13. Sectional drawing showing design and components of the fiberglass-armored Fig. 555G Graphite Ejector (4” and above).

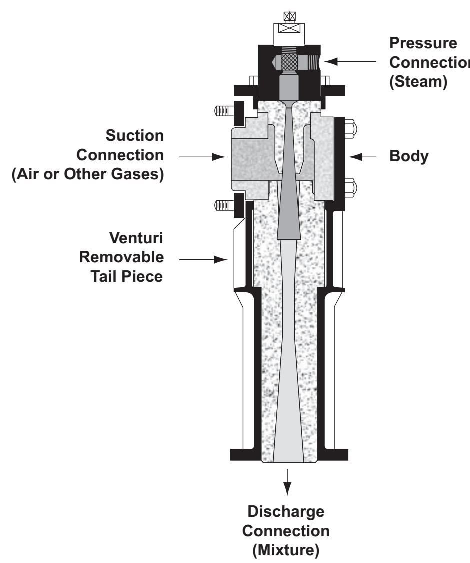
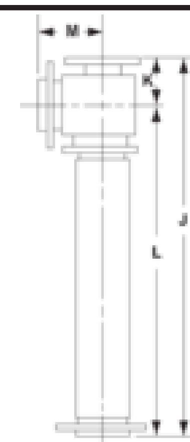


Fig. 14. Fig. 562 Ejectors with suction and discharge connections of less than 4” are metal armored as shown here.

Table 4. Sizes and Dimensions of Fig. 562/555G Ejectors (Graphite Construction)

Size No. (Inches)	Connections			Dimensions				Approx. Shipping Wgt. (Lbs.)
	Suction	Discharge	Steam Inlet	J	K	L	M	
1 1/2	1 1/2	1 1/2	1/2	19 13/16	4 7/8	12 3/4	3	60
2	2	2	3/4	22 5/8	5 1/2	14 3/4	3 1/4	75
2 1/2	2 1/2	2 1/2	3/4	26 7/16	6	18 1/16	3 3/8	89
3	3	2 1/2	1	30 7/16	6 1/8	21 13/16	3 3/4	122
4	4	3	1 1/4	40 7/8	5 5/8	35 1/4	6 1/4	260
5	6	5	3	52 3/8	6 1/2	45 7/8	8	320
6	6	6	3	61	6 1/2	54 1/2	8	400
8	8	6	3	ON APPLICATION				



SINGLE-STAGE EJECTORS

FIG. 557/542 SINGLE-STAGE EJECTOR

RELIABLE VACUUM PERFORMANCE

Application

- Designed to cover a suction pressure range from 1” to 29” Hg absolute
- Unit re-designed to offer integral cast motive flange
- Standard components in stock to allow for fast turnaround
- Units can be placed in series to attain high vacuum levels

Construction

- Body: Investment cast in SST 316
- Tail: Investment cast or fab with choice of SST 316 or carbon steel
- Motive connection available with 150# or 300# flanges

Mark No.	Description
1	Body
2	Tail
3	Nozzle
4	Capscrews
5	Pipe Plug
6	Gasket
7	Backing Flange (when needed)

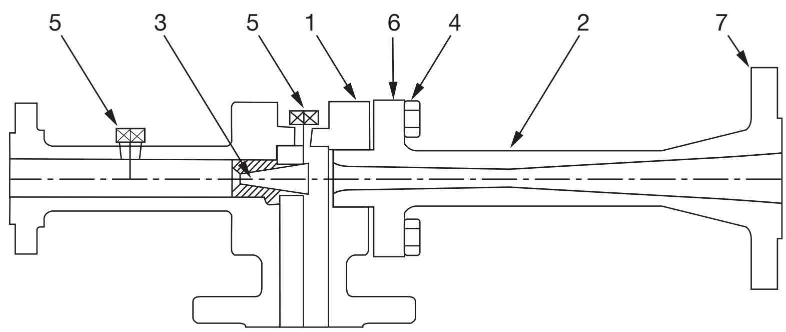


FIG. 557/542

SINGLE-STAGE EJECTORS

FIG. 557/542 SINGLE-STAGE EJECTOR

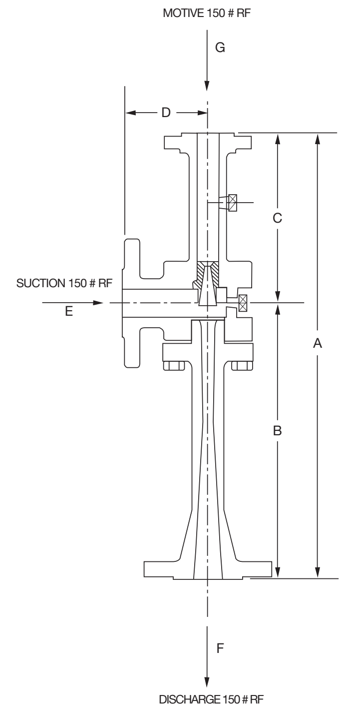


Table 5. Fig. 557/542 150# RF Motive Connection

UNIT SIZE	UNIT DIMENSIONS				E	F	MOTIVE SIZE	NET WT LBS
	A	B	C	D			G	
1	14 1/2	8 7/8	5 5/8	2 7/8	1	1	3/4	23
1 1/2	20	13 1/4	6 3/4	3 3/8	1 1/2	1 1/2	1	27
2	25 1/4	17 11/16	7 9/16	3 5/8	2	2	1 1/2	54
2 1/2	30 1/4	22 1/16	8 3/16	3 7/8	2 1/2	2 1/2	1 1/2	83
3	36 3/4	26 7/16	10 5/16	4 5/8	3	3	2	126
4	47 5/16	35 5/16	12	5 7/8	4	4	2 1/2	222
5	59	45 7/8	12	7 1/2	6	5	3	343
6	69 1/2	54 1/2	12	7 1/2	6	6	3	493

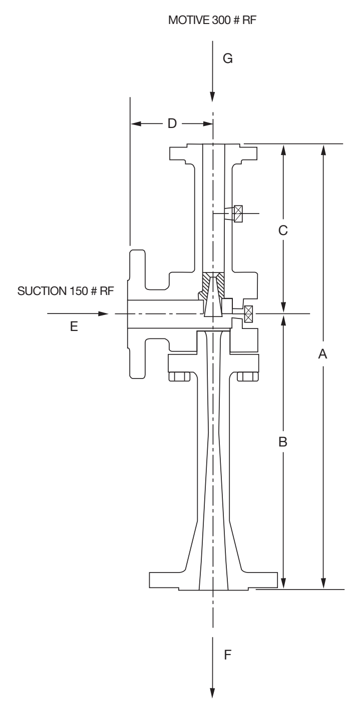


Table 6. Fig. 557/542 300# RF Motive Connection

UNIT SIZE	UNIT DIMENSIONS				E	F	MOTIVE SIZE	NET WT LBS
	A	B	C	D			G	
1	14 1/2	8 7/8	5 5/8	2 7/8	1	1	3/4	23
1 1/2	20	13 1/4	6 3/4	3 3/8	1 1/2	1 1/2	1	27
2	25 1/4	17 11/16	7 9/16	3 5/8	2	2	1 1/2	54
2 1/2	30 1/4	22 1/16	8 3/16	3 7/8	2 1/2	2 1/2	1 1/2	83
3	36 3/4	26 7/16	10 5/16	4 5/8	3	3	2	126
4	47 5/16	35 5/16	12	5 7/8	4	4	2 1/2	222
5	57 7/8	45 7/8	12	7 1/2	6	5	3	343
6	66 1/2	54 1/2	12	7 1/2	6	6	3	493

MULTI-STAGE EJECTORS

Staging of ejectors becomes necessary for economical operation as the required absolute suction pressure decreases (see Fig. 3, page 3).

Based upon the use of auxiliary equipment, two and three-stage ejectors can be either condensing or non-condensing types. Four, five and six-stage units can also be non-condensing, but usually are condensing types.

Condensing Type Ejectors (Fig. 16) have an intercondenser between ejectors that reduces steam consumption in later stages by (1) condensing first stage operating steam and condensable vapors; and (2) cooling the air and other non-condensables. The intercondenser may be direct-contact or surface type, arranged barometrically or low-level. Pages 11, 12 and 13 contain additional details on the Condensing Type Ejector.

When the condenser is mounted at barometric elevation, drainage is by gravity through a sealed tail leg so condenser and suction lines will not flood if steam service is interrupted or loss of vacuum occurs.

A ground-level arrangement suitable for many applications is shown on page 15, Fig. 26. This type of steam jet ejector is ideal for use when service conditions prohibit locating condensers at barometric height and direct contact condensing is permitted.

Non-Condensing Type Ejectors (Fig. 17) have the first stage ejector discharging directly into the suction of the second stage ejector and so on, using no condensers.

Compared to the Condensing Type Ejector, this arrangement imposes a greater load on subsequent stages, requiring more operating steam and larger units following. Non-Condensing Type Ejectors are used where condensers are not feasible, where initial cost is more important than operating cost, or when service is to be intermittent making operating cost a secondary consideration.

Both Condensing Type Ejectors and Non-Condensing Type Ejectors can be supplied with after-condensers. The aftercondenser condenses the operating steam and any condensable vapors before the non-condensables are discharged to atmosphere.

Except for units of low capacity or those used for intermittent service, condensing units are more economical in operation than non-condensing types, although initial cost may be higher. For photos of Multi-Stage Non-Condensing Ejectors, refer to page 14.

Fig. 16. Condensing Type.

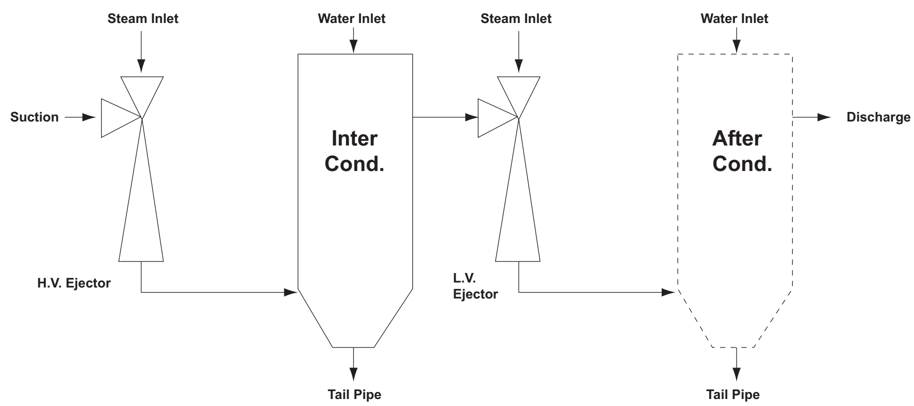
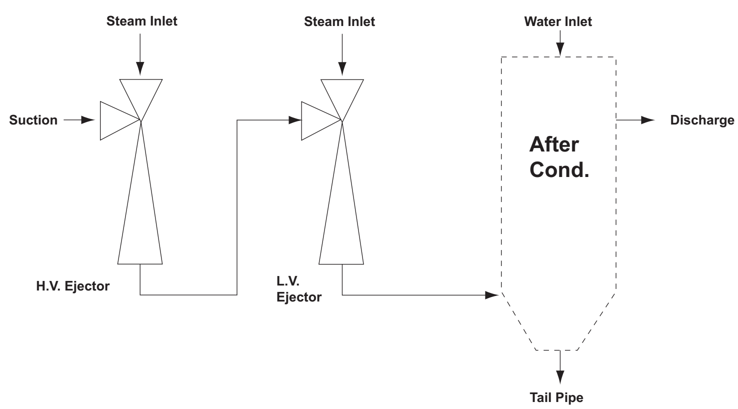


Fig. 17. Non-Condensing Type.



MULTI-STAGE EJECTORS

TWO-STAGE EJECTORS

Application

Two-Stage Steam Jet Ejectors have the same general field of application as the single stage units. They handle both condensable and non-condensable gases or vapors, as well as mixtures of the two. The general operating range is between 5" Hg. abs. and 3 mm Hg. abs. Depending on conditions, however, a single-stage unit may be more economical at the top of the range and a three-stage unit near the bottom.

Operation

In the two-stage assemblies, the suction mixture enters the body of the primary stage, or High Vacuum (H.V.) Ejector, Fig. 541, and is compressed from the required suction to an intermediate pressure less than atmospheric. The secondary stage or Low Vacuum (L.V.) Ejector, Fig. 556 compresses from this point to atmosphere, or to a point where it is desired to utilize the ejector discharge.

Exact value of the intermediate pressure varies with the operating conditions and the type of two-stage assembly. The units have been designed for optimum inter-stage pressure.

In condensing units, the inter-condenser functions as previously described. This reduces the load on the low vacuum ejector and reduces steam consumption. The intercondenser may be a direct-contact barometric type, a low level type, or surface type. These are discussed in more detail on pages 13, 14 and 15.

In small size units, and where cooling water is not economically available, the intercondenser may be eliminated, resulting in a two-stage non-condensing unit.

When the suction load contains a large amount of condensable vapors, it is sometimes possible to use a surface or direct-contact pre-condenser, or pre-cooler to reduce the load on the first stage ejector (Fig. 18). Also, if it is objectionable to discharge the low vacuum exhauster directly to atmosphere, an aftercondenser can be used to condense the steam and other condensables, as well as lower the noise level. Direct-Contact Condensers for this function are described in Bulletin 5AA.

Non-condensing two-stage units can be used when conditions warrant this type of arrangement. A typical arrangement is shown on page 14.

FIg. 18. Five Two-Stage Steam Jet Ejectors equipped with pre-condensers are shown installed on the roof of a chemical plant. Tailpipes on condensers are offset downward at a 45 degree angle to allow free flow of discharge water.

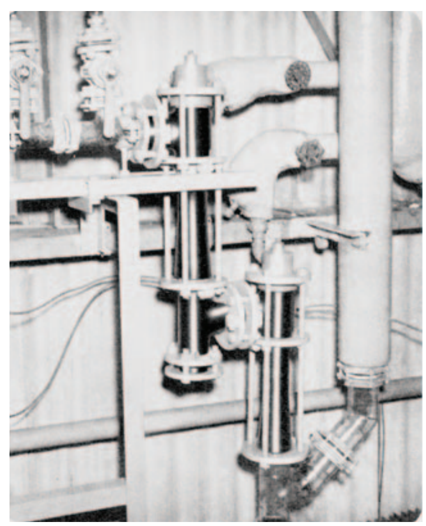


Fig. 19. The Two-Stage Non-Condensing Ejectors shown here are made of Phenolic FRP. The piston-operated shut-off valve shown in the suction line permits operation of the pump from a central control panel.

MULTI-STAGE EJECTORS

THREE-STAGE EJECTORS

Application

Three-Stage Ejectors are recommended for applications where a two-stage unit will not provide low enough suction pressure economically. Applicable range is from 26 mm Hg. abs. to 0.8 mm Hg. abs. but economics might dictate use of a Two-Stage Ejector at the upper part of the range and a Four-Stage Ejector at the lower end.

Operation

Three-Stage Condensing Steam Jet Ejectors consist of a booster ejector, a booster condenser, and a Two-Stage Ejector consisting of a high-vacuum ejector, intercondenser, and low vacuum ejector. In some applications another condenser (after-condenser) can be used at the low vacuum ejector discharge.

The type condensers can be direct contact or surface type arranged barometrically or low level. (See pages 11, 14 and 15).

The most economical type of three-stage ejector system uses direct-contact, barometric, countercurrent condensers which permit gravity drainage of the condensate and condensing water and eliminate the need for removal pumps. In cases where it is not possible to install the unit at barometric height (about 34 feet), the low-level arrangement (Fig. 26, page 15) can be used. In instances where contaminants are introduced into the condensers and cannot be discharged directly into drains, surface condensers are used to prevent discharge to drains and permit recovery or treatment of the contaminants.

In condensing units, the booster ejector operates at very high vacuum and discharges into a booster condenser. Process and booster ejector steam is condensed and the air and non-condensables are cooled and pass over to the second stage ejector. This continues through to the last stage (low vacuum ejector) where they are compressed to atmosphere or, if desired, into an aftercondenser. Cooling of non-condensables reduces the load on succeeding ejectors and minimizes steam consumption.

In general, units with direct-contact condensers require less steam and cooling water than do those with surface condensers.

Three-Stage Ejectors can also be of the non-condensing type. They consist of a booster ejector, high-vacuum ejector, and low-vacuum ejector, each connected to the other by piping. From the third stage, discharge is made to atmosphere or to a point where it is desired to utilize the ejector discharge.

Fig. 20. Typical Three-Stage Steam Jet Ejector. This unit is used in processing vegetable oils.

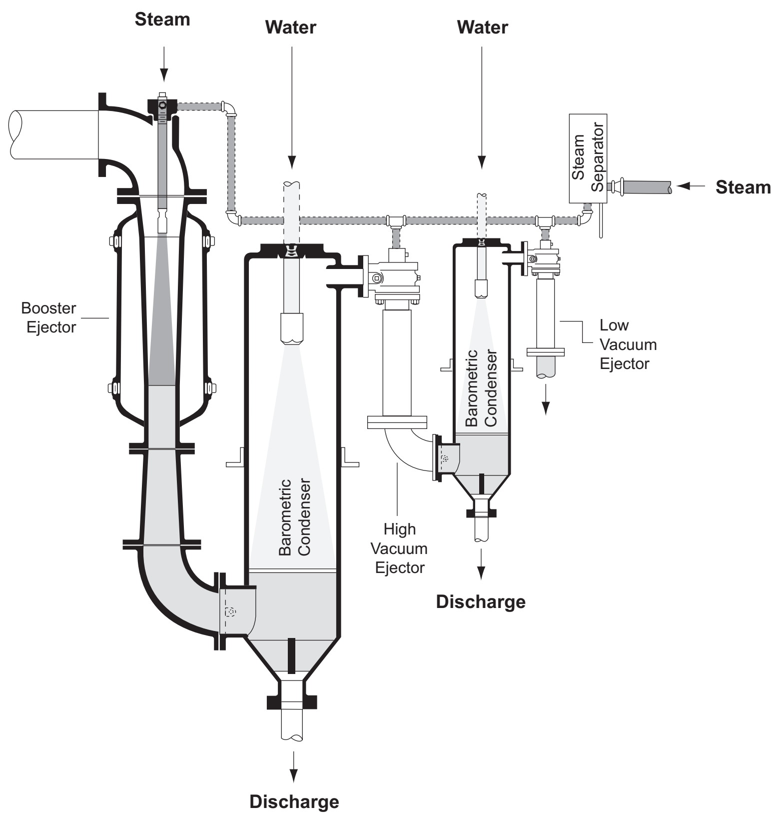


Fig. 21. Three-Stage Steam Jet Ejector. The booster ejector diffuser should normally be steam jacketed when design suction pressure is less than 4.6 mm Hg. abs.

MULTI-STAGE EJECTORS

FOUR, FIVE, AND SIX-STAGE EJECTORS

Application

Multi-Stage Ejectors have applications similar to those described on page 1 of this bulletin. These units are used for applications where required suction pressures are beyond the range of the ejectors previously described. Generally, suction pressure ranges are as follows (note overlap in bar chart. Fig. 3, page 3):

Four-Stage Ejectors—4 mm Hg. abs.
to 75 microns Hg. abs.

Five-Stage Ejectors—0.4 mm Hg. abs.
to 10 microns Hg. abs.

Six-Stage Ejectors—100 microns Hg. abs.
to 3 microns Hg. abs.

FOUR-STAGE EJECTORS

The four-stage unit consists of (1) a primary booster ejector; (2) a secondary booster ejector; (3) a high vacuum ejector; (4) a low vacuum ejector; and (5) usually two condensers—one after the secondary booster ejector and the other between the high vacuum and low vacuum ejectors. The condenser between the high and low vacuum ejectors is sometimes omitted, depending upon application requirements. Direct contact or surface condensers, arranged barometrically or at ground level, can be used. The four-stage is similar to the three-stage unit except that another booster ejector is added. In the four-stage, the primary booster is steam-jacketed to prevent build-up of ice on the diffuser internal bore.

In operation, the booster ejectors operate in series and discharge into a booster condenser, which removes the operating steam and condensable gases. From this point operation is similar to the two-stage ejector.

Final selection and arrangement of four-stage units will depend upon specific requirements.

FIVE AND SIX-STAGE EJECTORS

A typical Five-Stage Ejector is shown in Fig. 22. The five and six-stage units are similar in appearance to the four-stage ejector except that additional booster ejectors are added. Suction pressure ranges are as indicated under "application." The first two stages of these units are usually steam-jacketed.

While four, five, and six-stage ejectors are usually condensing types for reasons of efficiency and operating economy, it is possible to employ non-condensing types. Refer to S & K for information on operating characteristics of such units.

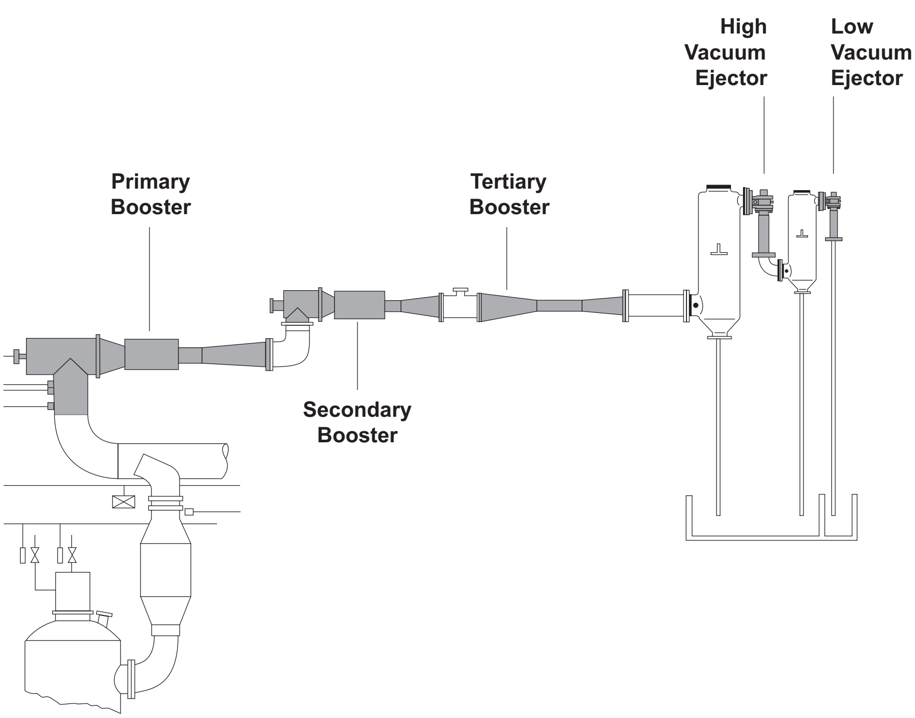


Fig. 22. Five-Stage Steam Jet Ejector.

MULTI-STAGE EJECTORS

EJECTORS WITH SURFACE CONDENSERS

Disposal of contaminated water is of growing concern in process operations, particularly in the chemical industry. Where an ejector system is drawing in contaminants, a condenser that discharges directly to the drain may not be used. In these applications, ejectors using surface condensers are being utilized more. The surface condenser prevents discharge to the drain and permits recovery or treatment of undesirable wastes.

A steam jet system with surface condensers normally requires more motive steam and condensing water than one with direct-contact condensers. This is the most expensive type of multi-stage ejector. It can be mounted at barometric elevation, but does not require this type of installation.

A typical multi-stage unit with twin ejectors for each stage and surface type inter - and aftercondenser is shown in Fig. 23. The purpose of the twin ejectors is to provide a spare set of ejectors that can be brought into service in case repairs are necessary on the other set. Isolating valves are used to allow removal of an ejector without breaking vacuum.

In certain applications, the twin ejectors are selected to provide more flexibility of operation under varying load conditions. In this case, each ejector for each stage would be sized to handle only half the load, so that the unit could operate at half-load with only one ejector operating in each stage.

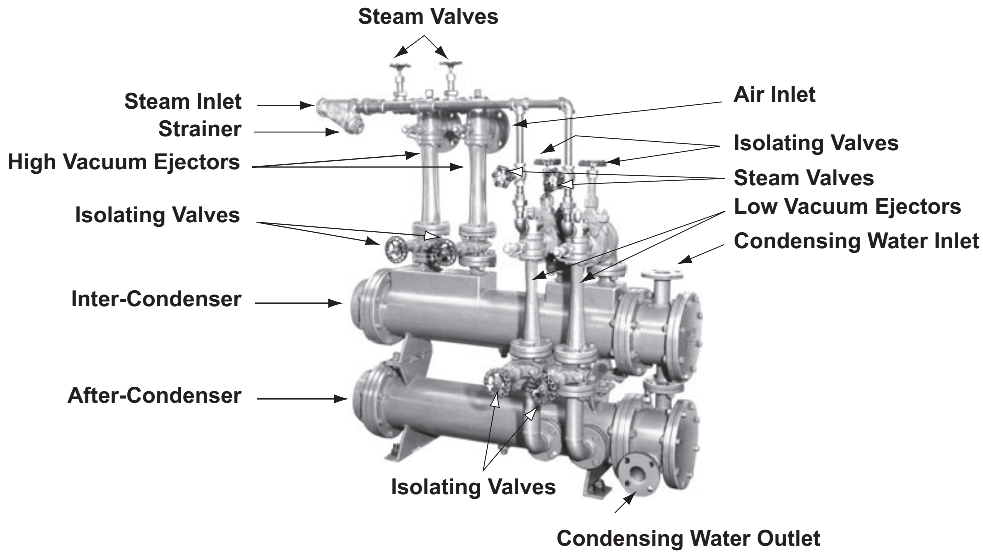


Fig. 23. Two-Stage Steam Jet Ejector System with twin ejectors for each stage and a surface type inter-and aftercondenser.

NON-CONDENSING EJECTORS

Shown are several examples of multi-stage non-condensing ejectors. This arrangement is generally utilized in situations where a barometric leg or cooling water is not readily available for an inter-condenser. They also can be furnished in Phenolic FRP or Graphite construction for corrosive applications. Non-condensing ejectors provide the lowest initial capital equipment investment for multi-stage systems.

Fig. 24. Two-Stage Non-Condensing Ejector.

Fig. 25. Three-Stage Non-Condensing Ejector.

MULTI-STAGE EJECTORS

LOW-LEVEL EJECTOR SYSTEMS

Application

Low-Level Ejector Systems have applications similar to those described on page 14. In cases where it is not possible to install the condensing portion at barometric height (34 feet), special designs can be used for "direct-contact" (Fig. 26) and "shell and tube" (Fig. 27) type low-level units. These units can be supplied as two-stage through four-stage systems ready for operation at job site simply by providing steam, water and electrical connections.

Operation

DIRECT CONTACT LOW-LEVEL ARRANGEMENT

This type uses a direct contact condenser with an integral reservoir and a float-operated water control valve to maintain a constant operating head above the condensate removal pump. Since heat is introduced by the process, it is necessary to maintain proper condensing water temperature by providing appropriate bleed and make-up water.

SHELL AND TUBE LOW-LEVEL ARRANGEMENT

Standard shell and tube heat exchanger and a pump operated water jet ejector are installed below the exchanger to remove condensate. The condensate removal system does not need make-up cooling water after initial operation.

The steam jets supplied on both low-level types are the same as supplied for barometric installations.

Fig. 26. Four-Stage Low-Level Steam Jet Ejector with an integral reservoir, a water removal pump and level control.

Fig. 27. Two-Stage Low-Level arrangement with shell and tube heat exchanger.

Fig. 28. With available head room at an absolute minimum, S & K engineered this three-stage low-level, condensing unit to eliminate the need for a barometric leg.

CORROSION RESISTANT MULTI-STAGE EJECTORS

Selection of suitable materials for the specific pumping application is an important consideration. To insure minimum maintenance and replacement costs, Multi-Stage Steam Jet Ejectors are available in many corrosion resistant materials. Figures 29 and 30 show units made of Phenolic FRP and Graphite. See page 2 for other special materials. Condensers are frequently made of polyester fiberglass or steel with neoprene lining.

Fig. 29. Standard Phenolic FRP Construction with interconnecting tee and target plate to take steam impingement.

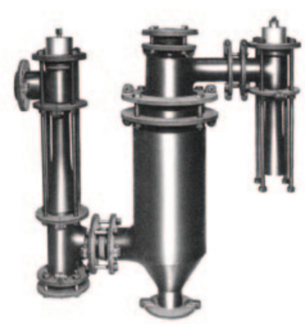


Fig. 30. Standard Graphite Construction (Phenolic FRP Intercondenser).

MULTI-STAGE EJECTORS

STEAM JET VACUUM BOOSTERS

Application

If large condensable vapor loads must be handled, such as those from an evaporator or crystallizer, it is normally done with a condenser followed by a single-stage or two-stage ejector. The condenser condenses the vapor and the secondary unit removes the saturated non-condensables and maintains the vacuum.

The vacuum obtainable in a condenser is limited by the vapor pressure of the injection water. If a higher vacuum is desired, a Steam Jet Booster is provided to increase the vacuum to the desired point. Boosters like this are used in multi-stage units. The booster ejectors are large in proportion to the other ejectors because of the magnitude of the vapor load they handle.

The function of the Steam Jet Vacuum Booster is to compress the condensable and non-condensable vapors from the suction vacuum to the intermediate vacuum maintained in the condenser.

Fig. 31 shows a typical Steam Jet Vacuum Booster and its construction. The vacuum booster is made of fabricated steel and has a nozzle which can be easily removed for examination or cleaning without dismantling the booster body or pipe connections. The nozzle can be cast or fabricated of special materials if necessary.

The Fig. 533 Vacuum Booster is designed to handle large quantities of condensable vapors plus relatively small quantities of non-condensables in a pressure range of 5 to 25 mm Hg. abs.

Fig. 32 shows a three-stage unit with a Steam Jet Booster exhausting into a barometric condenser. Similar arrangements are used extensively for vacuum distillation in oil refineries and for other chemical processes, as well as for concentrating and crystallizing liquids. Such an arrangement is also used to remove vapors from a flash evaporator of a steam jet refrigeration system.

Operation

The Jet Vacuum Booster is designed to operate with steam pressures as low as 5 psig. In operation, the steam issues from the nozzle and creates a vacuum in the booster body. Suction steam and vapors are drawn into the booster and entrained by the operating pressure steam then discharged into the booster condenser where steam and condensable vapors are condensed.

Fig. 31. 30-inch vacuum booster with carbon steel body and stainless steel diffuser.

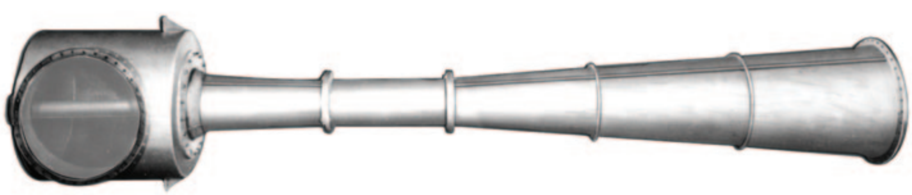
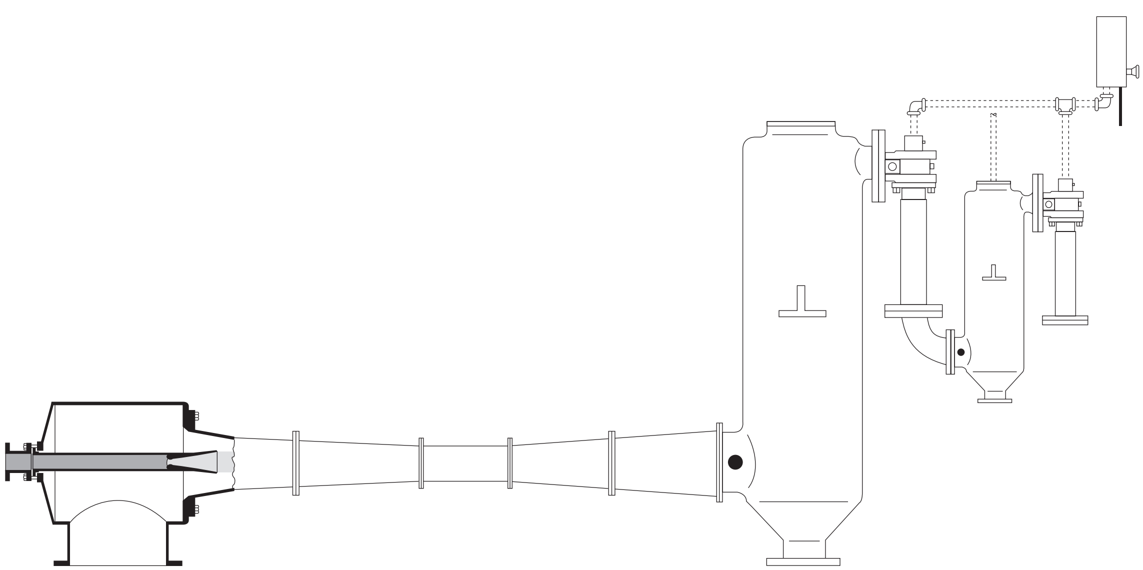


Fig. 32. Typical arrangement of a Three-Stage Steam Jet Ejector with a Steam Jet Booster.



APPLICATION CONSIDERATIONS

Operating Steam Pressure

All ejector nozzles are designed for a specific steam flow and pressure. This pressure must be maintained to insure stable and satisfactory operation. Should the steam pressure drop below the design pressure, the vacuum will drop and the stability of performance will be upset. It is, therefore, of the utmost importance when ordering an ejector to specify the minimum steam pressure available at any time at which the apparatus may have to operate.

Should the steam pressure be increased above the design pressure, the ejector will operate satisfactorily with only a slight decrease in capacity and with an increase in steam consumption in direct proportion to the increase in the absolute pressure. Where the operating steam pressure is likely to vary over a wide range, we recommend the installation of a suitable pressure regulating valve in the steam line. Since moisture in the steam will cause excess wear and erratic operation, a steam separator is recommended.

Back Pressure

Standard ejectors are designed to operate against a back pressure not exceeding 1 psig. It is possible, however, to design them to operate against higher back pressures, depending on the vacuum to be maintained and the available operating steam pressure. However, ejectors should not be operated against a back pressure higher than that for which they are designed.

MEASUREMENT OF LOW ABSOLUTE PRESSURES

Following are precautions to use in connection with steam jet ejectors:

1. Do not depend upon spring type vacuum gauges or absolute pressure gauges involving one sealed leg when perfect vacuum is assumed.
2. Gauge tubes should be clean and free of contamination.
3. Gauge liquid should be clean and free of contamination.
4. Barometer should be located near mercury manometers.
5. If the operating point is 0.04 in. (1 mm) Hg. abs. or less, rubber tubing should not be used. Copper tubing or plastic tubing with a minimum bore of 3/8" should be used in this case.

The following gauges are recommended for use with the vacuum pressures noted:

1. Absolute pressure of 4 in. Hg. to 0.5 in. Hg. Use a mercury column or manometer using straight tube with scale graduated to 0.1 in. and a vernier reading to 0.01 in.
2. Absolute pressures of 12.7 mm Hg. to 1.0 mm Hg. Use a Butyl Phthalate or similar differential oil manometer.
3. Absolute pressures of less than 1.0 mm Hg. Use the following:

   a. A suitable McLeod gauge or oil manometer. The McLeod gauge should be used without freezing trap or mechanical dryer. The gauge and mercury must be clean and the system tested to make certain there are no leaks.

   b. A suitable indicating vacuum gauge to be connected in parallel with the McLeod gauge. This indicating gauge can be a differential oil manometer if the pressure is above 0.5 mm. Between 1 micron and 1 mm, an ionization gauge or Piranni gauge may be used. The purpose of the indicating gauge is to show the observer when the pressure is steady enough to take a reading with the more accurate McLeod gauge.

DATA REQUIRED FOR QUOTATION

In order to select the type, size, and capacity of exhauster to meet specific requirements, the following information should be supplied with inquiries:

1. If multi-stage unit, specify type of unit desired (condensing or non-condensing).
2. Fluid to be handled in lb. per hour or standard cfm. If other than air or water vapor, the molecular weight and specific heat should be given. Vapor pressure of condensables other than water vapor is also required.
3. Materials of construction required. If this is in doubt, an analysis of the suction fluid should be presented to aid in making the proper selection.
4. Temperature of suction fluid at exhauster inlet.
5. Pressure desired at ejector suction, in inches, millimeters, or microns of mercury absolute.
6. Minimum pressure of operating steam stating whether steam is dry, saturated or superheated, giving degree of superheat, if any.
7. Maximum temperature of water available and minimum pressure of condenser inlet.
8. State whether final stage ejector is to operate against atmospheric pressure or a higher back pressure, and if so, what pressure.
9. Normal barometer reading at installation.
10. Type of condenser desired—direct contact or surface type (if required).
11. Type of installation desired-barometric or low level. If low level, state electrical code the removal pump must meet.

Fig. 33. These two steam jet ejectors serve as part of the pressure recovery system at the U.S. Army's high energy laser system test facility in White Sands, New Mexico. They are each 97 feet long with 96 inch diameter end-suction connections, and are among the largest ever manufactured anywhere. Each ejector handles a large quantity of low molecular weight gas at 120 Torr using the equivalent of 1.044 million pounds of steam per hour at 150 psig during the 14-second cycle.

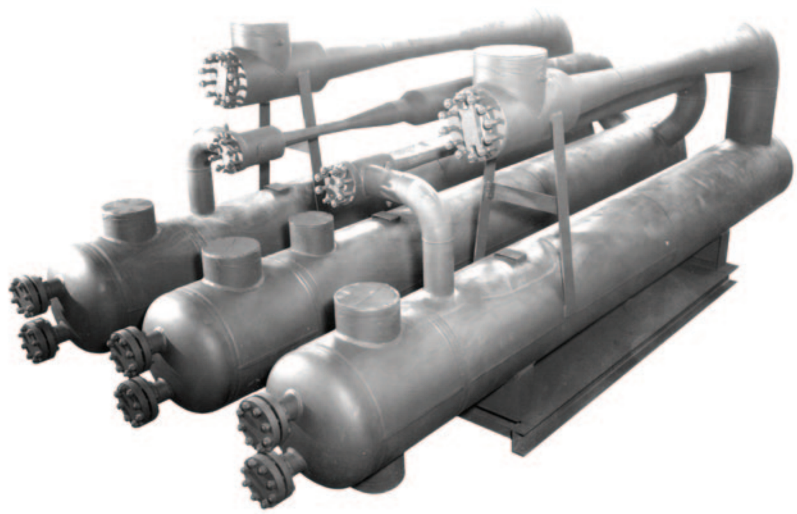


Fig. 34. This compact, twin-element, two-stage steam jet ejector saves space in a nuclear power station. Each first-stage ejector discharges into a separate intercondenser, while both second-stage ejectors discharge into a common after condenser. Twin element designs of the type shown provide uninterrupted service. Either element can be taken out of service for periodic inspection and cleaning while the other continues to function.